1. ELECTRICAL SYSTEMS MANAGEMENT

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APPENDICES

ELECTRICAL SYSTEMS MANAGEMENT – POTENTIAL FOR SAVINGS

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1.0 INTRODUCTION

Electrical energy management mainly aims at efficient use of Electricity in any plant or organisation. Efficiency here can be defined as output of any plant/ equipment/ process per unit consumption of energy. Increasing efficiency means increasing the production for the same consumption of electrical energy or reducing the energy consumption for the same output. Specific energy consumption ie., energy units consumed per unit of production can also be treated as an index of energy efficiency.

2.0 ENERGY AUDIT APPROACH

It is needless to stress the importance of improving the energy efficiency under present constraints of cost and availability . A broad classification of area of concentration for improving the electrical energy efficiency would be -

1. Energy conservation in plants/equipments/ process
2. Savings in energy consumption

Energy conservation measures aim at improving the efficiency/performance of equipments under different operating conditions.

Savings in energy consumption can be achieved by enforcing suitable house keeping measures and eliminate avoidable consumption of energy.

2.10 ELECTRICITY INFORMATION AND MONITORING SYSTEM

It is important to note that a proper monitoring, information and accounting system will yield about 5% of savings in energy consumption. The main object of the Energy Information System is to collect sufficient data on energy consumption, production and energy efficiency.

It helps –

– to identify high energy consuming areas/equipments/process

– to establish specific energy consumption figures Dept. wise/equipments/process-wise reasonably

– to fix an overall plant efficiency index

It has been observed that with few exceptions energy information systems are non -existent or primitive even in large plants with high monthly electricity bills.

Providing energy meters for high energy consuming plants/ sections/equipments/process should be mandatory. Even medium sized motors/equipments which are continuously used for over 7500 hours in a year should be considered for metering. The cost of such metering would be less than 1% of cost of energy consumption at these points. While selecting location of energy meters, care should be taken to see that the consumption for important equipments/plants like cooling towers, humidification plants/ Heat treatment and Melting furnaces/ Compressed air systems are available. It is advisable to get calibrated, all the meters including the meters supplied by the Electricity Board periodically.

After arriving at the individual consumption on a daily/weekly basis, the total consumption has to be compared with the consumption recorded in the main meter of the Electricity Board. After allowing a reasonable percentage (between 2% to 5%) for transformer and Distribution losses, any discrepancy needs to be investigated .Variations on consumption due to low production or idle running etc., should be properly accounted. It is advisable to develop separate energy efficiency indices for various equipments and process. A periodical review of these indices is also necessary. It should be possible to run most efficient equipments available.

2.20 ANALYSIS OF CONSUMPTION PATTERN AND ASSESSMENT OF SYSTEM PARAMETERS

An objective analysis of consumption patterns, load demand, loading conditions, Daily load curves, is very much essential to have an overview of the system and also for identification of high loss zones. Measurements of various system parameters on a daily/weekly/monthly basis depending on the type and loading conditions would enable us to arrive at various system indices such as Load factor, Loss load factor , Diversity Factor, Utilisation Factor, etc. These measurements can be carried out using the meters normally provided at the Panel Boards during typical working days/weeks/seasons and also on Annual basis. This involves collection of measured data and further analysis. Triline Energy Monitor (Synergy Meter) would be a very useful and versatile measuring instrument in this regard. With the help of this instrument all the relevant parameters can be measured, stored and dumped on to a computer as input data. Using this input data and necessary software, further analysis and assessment of system parameters and system factors can be worked out. Some of the definitions/formulae and calculations for these system - Factors have been placed in Appendix-I. Another useful instrument in this regard is the "power Analyser" with which the instantaneous values of the system parameters during working condition of each equipment can be measured.

3.0 LOAD MANAGEMENT AND MAXIMUM DEMAND CONTROL

Electricity demand and supply should match instantaneously . This needs reserve capacities kept already to meet the peak demands. Hence the cost of Peak Demand or normally referred to as Demand charges are considerably high. In India at present the Demand charges do not fully reflect the Marginal costs. Marginal Demand charges are in the range of Rs.200/KVA month. A review of tariff revisions indicate a tendency to hike the demand charges and also introduction of time of the day metering. As such, there is a need for integrated load management to effectively control the Maximum Demand and its appearance during peak/off peak periods.

A detailed study of the load curve and load factor indicates the scope for effecting the M.D. control. It is preferable to flatten the load curve as far as possible and hence to improve the load factor . Load factors for a wide variety of industries have been shown in Table in Appendix- II. The load factor will be normally highest for continuous process industries and least in case of engineering and fabrication industry. To improve the load factors, it is necessary to reduce the peak demand which may be occurring only for short periods. The peak demands can be measured using demand indicators. In the absence of these meters, a measurement of current and voltage values every half an hour would give a reasonable value of demand. Graph in Appendix-III indicates a daily demand curve for a typical engineering industry. Plotting daily demand curve for a month will immediately give an idea when peak demands are occurring. Some of the methods employed in load management are discussed

in the following paragraphs.

3.1 RESCHEDULING OF LOADS

Rescheduling of high unit loads and operations, in different shifts can be planned and implemented to minimise the simultaneous maximum demand. For this purpose it is advisable to prepare an operation flow chart and a process run chart. Analysing these charts and with an integrated approach it is possible to reschedule the operations and running heavy equipments in such a way as to reduce to the maximum demand and improve the load factor.

CASE STUDY

In a typical wire drawing industry 3 nos. of preliminary wire drawing equipments having load of 50 HP each were used simultaneously in the day shift. The simultaneous maximum demand offered by the overall plant was about 450 KVA. It was rescheduled to operate the above equipments in 3rd shift . In third shift only few equipments (light load) were being operated. With this proposal the M.D. was reduced by 150 KVA resulting in savings of about Rs. 90,000 per annum in Demand charges apart from flattening of the load curve to a considerable extent.

3.2 STAGGERING OF MOTOR LOADS

When running of motors of large capacities are involved, it is advisable to stagger the running of these motors with a suitable time delay (as the process may permit) so as to minimise the simultaneous maximum demand (depending on conditions of load) offered by these motors.

CASE STUDY

In a pipe manufacturing industry, three automatic moulds with motor loads of 70 KW were being operated simultaneously. The operators were instructed to follow a time delay in running these motors (with limitations of process requirements). This resulted in reducing the maximum demand to a considerable extent (about 50 KVA) and savings of about Rs. 30,000 per annum in Demand charges.

3.3 STORAGE OF PRODUCTS

It is possible to reduce the maximum demand by building up storage of (1) Products/materials (2) water or other liquids (3) Chilled water/Hot water using electricity during off peak periods. Additional cost of machinery and storage are justified in many cases by reduction in demand charges. Eg. Chilled water storage at night to provide day time air conditioning, additional raw material/ clinker grinding facilities in cement plants, storage of chipped wood in paper plants.

However, benefit/cost analysis has to be worked out for the above and considered for implementation if it is economically viable.

3.4 SHEDDING OF NON ESSENTIAL LOADS

When the maximum demand tends to reach a preset limit, it can be restricted by shedding some of the non essential loads temporarily. It is possible to install direct demand monitoring systems which will switch off non essential loads when a preset demand is reached. Simple systems give an alarm, and the loads are shed manually.

Sophisticated microprocessor based systems are available which provide a wide variety of control options. These systems provide the following options.

1. Accurate prediction of Demand
2. Graphical display of present load, available load, demand limit
3. Visual and audible alarm
4. Automatic load shedding in a predetermined sequence
5. Automatic restoration of load
6. Recording and metering

These systems are widely used abroad, but their use in India has been rather limited. Simple load management systems with manual load sheddings operations are being employed in several industries.

CASE STUDY

A simple M.D. monitor and control system with audible alarm has been employed in a engineering industry to maintain a preset M.D. When the present value is reached, non essential loads such as Air conditioning, blowers and some lighting circuits are switched off.

3.5 OPERATION OF DIESEL GENERATION SETS

When D.G.Sets are used to supplement the power supplied by the Electricity Boards, it is advisable to connect the D.G.Sets for loads which contribute for sharp peaks. This would reduce the load demand to a considerable extent and minimise the demand charges.

If Diesel generation takes place at the same voltage as that of the supply authority, then it is advisable to run both the supplies in parallel. This would result in considerable reduction in the Maximum Demand as the Diversity offered by all the loads at the plant level is made use of for sharing the peak load of the system.

4.0 TRANSFORMER LOAD MANAGEMENT

Transformers are provided for stepping down the voltage from supply level to operating level. All the electrical energy consumed by the Industry passes through the transformers. These are static type of equipments normally in operation through out the day. The efficiency of transformers depend on the loading conditions. At optimum load conditions the efficiency would be around 98%. As the load conditions fluctuate widely over a period of 24 hours, the All day efficiency of these transformers (by and large) normally are poor (around 96%). Even a small improvement in efficiency would result in considerable savings in energy losses in terms of kWh. By experience it is observed that the average loading conditions on the transformers are quite poor thereby reducing the all day efficiency. It is advisable to have more no. of small/medium sizes transformers than having one or two big size transformers. Such an arrangement would provide flexibility in operation of transformers to minimise the losses and also provide standby arrangement in case of failure of one of the transformers.

Transformer load management aims to achieve optimum loading conditions on transformers to minimise the energy losses in transformers and hence to improve the All day efficiency.

Following measurements are essential for effecting an ideal transformer load management

- Peak loads on individual transformers
- Overall system peak load
- energy delivered by the transformer

Peak loads on individual transformers as well as system peak loads are to be studied during representative

production months over a period of one year. Based on the data pertaining to the connected loads which can be conveniently divided into subcircuits/sub systems, the Diversity factor for each subsystem has to be arrived at, Diversity factor offered at the over all plant level also has to be worked out. Based on the peak load measurements and diversity factors, a scheme for operation of transformers (either in parallel or switching off some of them in cyclic rotation over a fixed period) can be worked out to achieve optimum loading conditions on the transformers. The peak load measurements can be carried out using Energy monitor or the Ammeter/ watt meters provided on the panel board. A detailed study of the log book maintained at the substation would help to arrive at Daily/Monthly Annual peak loads in individual cases and also at the overall system level. While working out the scheme for transformer load management, sufficient care should be taken to see that the no individual transformer unit gets overloaded for longer periods. Intermittent over loading as per IR ratings prescribed under BIS and ASA can be adopted wherever required. Permitted short time overloads as per ASA: C-57-32:48 has been shown in Appendix I- (10).

Transformer load management schemes have to be tailor made to suit individual requirements. A detailed study of the loading pattern and analysis of consumption would be required to examine various permutations and combinations of operating transformers in parallel or switching off of some units and evolve the most optimum condition. Such analysis can be best done using a computer and necessary software. Though a general approach for developing a standard software would be difficult, software modules to suit different condition can be developed using a modular approach. The software can also be designed to quantify the savings in energy loses and workout the benefit cost analysis for each scheme.

The cost of investment for the schemes can be worked out depending on the controls to be provided for alterations in cables/buses or relocation of LT panels or provision of bus couplers. By experience it is observed that the cost of investment in most of the cases would be marginal or the pay back would be within a reasonable period of about 2 years or less. Some of the case studies on transformer load management has been discussed in the following paragraphs.

4.1 CASE STUDIES

CASE STUDY - 1 TYPE OF INDUSTRY : MIXED LOADS

TRANSFORMER DETAILS

3 X 1000 KVA, 11 KV/440V, 3 ph,

DY11, Indoor type

Operated Independently

Bus couplers provided - 2 nos. inter connecting 3 sections of L.T. Panel

OCB's provided for each transformer on 11 KV side

LOADING CONDITIONS

Peak load on TR1 : 550 KW Dedicated supply with D.G. Set run during 1st shift

Peak load on TR2 : 300 KW

Peak load on TR3 : 350 KW

Peak load on TR1 : 200 KW - switched on during 2nd and 3rd shift only

SYSTEM FACTORS

Diversity factor	=	2.6 (Plant level)
Diversity factor	=	2.2 (Transformer wise)
Load factor	=	0.69
Loss Load factor	=	0.572
All day efficiency	=	95.05%

PROPOSAL

By operating the Bus coupler between transformer 2 and 3, it was proposed to open out 1 x 1000 KVA (either TR2 or Tr3) alternately in cyclic rotation of 72 hrs. TR1 also to be switched off during 2nd and 3rd shift shifts by closing the bus coupler between TR1 and TR2.

RESULTS

Peak load on TR2/TR3 : 542 KW (day peak)

D.F. (Inter transformers) ; 1.19

Peak load on TR1/TR2/TR3 : 371 KW (during 2nd and 3rd shifts

Estimated savings in energy : 93,000 kWh/Year in energy losses in the transformers

All day efficiency	=	96.65%
Cost of investment	=	NIL

CASE STUDY- 2

Type of Industry : Textile

Contract Demand : 3600 KVA

Maximum Demand : 3060 KVA

Installed capacity of transformers : 5100 KVA

Expected peak after expansion project : 3400 KVA

Transformer details

6 x 600 KVA 11KV/440V - TR Nos. 1 to 6

1 x 500 KVA 11KV/440V - TR NO.7

1 X 1000KVA 11KV/440V - TR NO.8

Transformer No.	Present peak load in KW	Present All day efficiency %		Remarks
1. TR NO.1	470	97.92	]	Operated in
2. TR NO.2	470	97.92	]	Parallel
3. TR NO.3	290	95.89	]	do
4. TR NO.4	300	95.89	]	do
5. TR NO.5	360	96.98	]	do
6. TR NO.6	240	96.98	]	
7. TR NO.7	260	96.98	]	

SYSTEM FACTORS

Load factor : 82.8%

Diversity factor : 1.66 (Based on installed capacity)

Loss load factor : 0.411

PROPOSAL

1. TRANSFORMER NOS. 1,2, & 3

At present Trs 1 and 2 are operated parallel by operating bus coupler. It is proposed to open out 1 x 600 KVA Transformers alternately in cyclic rotation of 72 hrs. The other two transformers would be operated in parallel.

2. TRANSFORMER NO. 4 & 5

At present they are operated in parallel. It is proposed to open out 1 x 600 KVA alternately in cyclic rotation of 72 hrs.

3. TRANSFORMER NO. 6 & 7

At present they are operated in parallel. It is proposed to open out 1 x 600 KVA alternately in cyclic rotation of 72 hrs.

RESULTS OF COMPUTATIONS AND COMPUTER RUN

TR NO.	PEAK LOAD KW	ALL DAY EFFICIENCY %
TR NO.1,2,& 3	1057	98.47
TR NO.4 & 5	440	97.90
TR NO. 6 & 7	433	97.91

Estimated savings in energy losses : 1,32,000 kWh/Year

Cost of investment : Nil

CASE STUDY : 3

Type of industry : Mixed loads - continuous process and engineering

Transformer details : 2 x 1000 KVA 11 KV/440V TR NOS. 1 & 2

DY 11, INDOOR TYPE

Operated independently

Bus couplers provided between L.T. Panels of Tr.No. 1 and 2: OCB's provided for each transformer on 11 KV side.

Peak load on TR NO 1 : 315 KW

Peak load on TR NO.2 : 312 KW

SYSTEM FACTORS

Diversity factor : 2.2

Load factor : 0.539

Loss load factor : 0.39

All day efficiency: 97.15%

PROPOSAL

To open 1 x 1000 KVA transformer alternately in cyclic rotation of 72 hrs.

RESULTS

Peak load on TR1/TR2 : 570 KW

Diversity factor (Inter transformer) : 1.15

Estimated savings in energy losses : 44,251 kWh/year

Cost of investment : NIL

4.2 OPERATION OF OLTC's

In medium and big industries the power supply is availed at EHT voltage ie., 33 KV and above. There will be two stages of step down (voltage-wise) in such cases. By providing and operating OLTC's to the power transformers and or/distribution transformers, it is possible to maintain an optimum voltage level on the 11 KV bus (slightly on the higher side). This reduces the current flow (for the same load conditions) in the transformers, buses and cables resulting in reduction of energy losses. Optimum level of the voltage to be maintained on the 11 KV side depends on the no. of taps available both at the sending end and receiving end side and also the flexibility of operation. The following case studies illustrate such an operation.

CASE STUDY 4

Type of Industry : Continuous process furnace loads (power intensive)

Contract Demand : 16.00 MVA

Maximum Demand : 14.00 MVA

Details of Transformers

Power transformers : 66/11KV

1 x 12.5 MVA and

1 x 7.5 MVA

DISTRIBUTION/FURNACE TRANSFORMERS

–	1.	1 x 1000 KVA,	11KV/433V,	DY11 OLTC
–	2.	1 x 1500 KVA,	11KV/433V,	DY11 OLTC
–	3.	1 x 1000 KVA,	11KV/433V,	DY11 OLTC
–	4.	1 x 1600 KVA,	11KV/433V,	DY11 OLTC
–	5.	4 x 2000 KVA,	11KV Class,	OLTC Furnace

OLTCs provided for distribution/furnace transformers and are operated to maintain an L.T. voltage of 440Volts (desired value) by automatic control (as well as manual operation) and operation of OLTC. OLTC's not provided for power transformers.

Incoming voltage at 66 KV bus: Very poor - varies from 52 KV to 66 KV over a period of 24 hrs depending peak load and off peak load hrs.

Corresponding voltage on 11 KV bus : 8.6 to 11 KV

Distribution system :

11 KV cable system drawn over considerable distances since distribution transformers are located at load centres.

System factors = Load factor : 0.6338
Loss load factor : 0.495
Diversity factor : 1.7

PROPOSAL :

To provide OLTC's for power transformers and operate the OLTC in such a way as to maintain 11.7 KV/at 12KV on the 11 KV bus always.

Results of computation

Estimated savings in energy losses : 4.82 lakh/kWh year

Net cost of implementation : Rs. 21 lakhs

Simple payback period : about 2 1/2 Years

CASE STUDY 5 :

Type of Industry : Mixed loads

(Continuous process furnace loads and engineering tool room)

Contract Demand : 4 MVA

Maximum Demand : 3.2 MVA @ 20% cut

Transformer Details

Power Transformer : 1 x 5 MVA 6 KV/11KV OLTC provided

DISTRIBUTION TRANSFORMERS

3 X 1000 KVA 11KV/440V Non OLTC

2 x 750 KVA 11KV/240V Non OLTC

1 x 1000 KVA 11KV/240V NOn OLTC

Distribution transformers have off load tap charging arrangement with +/- 5% variation.

Distribution system

11 KV cables have been drawn out for considerable distance since the distribution transformers are located at load centres

SYSTEM FACTORS

Load factor : 0.6552

Loss load factor : 0.4971

Diversity factor : 2.2

PROPOSAL

It was proposed to put the taps of all the distribution transformers at No.1 i.e., 5% above the normal. Operate the OLTC of the power transformer to maintain a voltage of 11.50 KV/11.55 KV on the 11 KV bus.

·Results of computation

Estimated savings in energy losses : 1.55 Lakh kWh/year

Cost of investment : Nil

5.0 SYSTEM POWER FACTOR AND USE OF CAPACITORS

Inductive type of loads such as Induction motors, Induction furnaces, Arc welders, transformers etc., operate at a low power factor and hence draw a large reactive component of current. This leads to fall in over all system power factor and reduction in line/switchgear capacities. Due to increase in current for the same power, energy losses will increase. Electricity supply authorities insist that the plant power factors to be maintained at 0.85 or 0.9. If the P.F. is less then penalties are levied. Some Electricity Boards give incentive for high power factors also. Hence it is necessary to provide capacitor units and maintain the power factor at 0.9 or higher. Table in Appendix III indicates the selection of capacitor sizes under various conditions.

5.1 LOCATION OF CAPACITORS

The location of capacitors at the substation would improve the overall power factor and the supply authorities would be satisfied in calculating the overall average power factor. For this purpose connection of capacitors at the H.T. side is good enough. The cost of the H.T. capacitor per KVAR is also lower. But the cost of connected controls and switchgear is quite high. Plant operations can also get affected due to capacitor problems. Major disadvantage in such case would be that the reactive currents flow through the L.T. cables and transformers leading to higher losses and lower equipment capacity. Capacitor can be connected on L.T. side of main substation. This also does not help in reducing distribution losses. It is always better to connect suitable capacitor (of smaller units) directly with motors or group of motors at the distribution point or sub distribution boards. A small no of capacitors may be kept at main substation for correction of small distributed loads.

When capacitors are switched on without loads the plant will operate at leading power factor and voltage may raise to a small extent. Daily variations in supply voltage are far more significant. Automatic P.F. correction equipment are required only in special cases. However this problem is over come by providing the capacitor units at the terminals of the motor equipments.

5.2 CAPACITORS FOR INDUCTION MOTOR LOADS

Induction motors contribute for the major quantum of reactive power flow in any plant. Correction of power factor at the motor terminal itself has the following advantages.

a) No additional switch gear

b) Switching on and off with motor means that no separate control is required

c) Reduced effect of motor in such currents

d) Minimum switching transient disturbances for other loads

e) Reduction of distribution cable current and resultant reduction of losses and heating effect.

Generally compensation at motor terminals is restricted to correcting the no load current so that at full load the pf is corrected to 0.9 to 0.95. At partial load the P.F. would be near unity Table 3 gives typical values of capacitors to be connected directly with Induction Motors.

Disadvantages with direct connection are -

excess voltage due to self excitation after switching off and large transient torque after fast reclosure. These difficulties are only encountered in a few cases where large capacitors are connected. For heavy inertial loads, after deenergisation, the motor works as an Induction Generator and excessive torque and currents can result if motor is started immediately. Table in Appendix IV gives the size of capacitor required for induction motors.

5.3 CAPACITOR FOR OTHER LOADS

Induction furnaces and Induction heaters require special attention. The operating frequencies and load characteristics change during melting and heating cycle. The capacitors are normally designed and supplied with control gear by the manufacturers. Capacitors for arc furnaces also need to be designed with care due to wide variation of PF during the melting cycle. The P.F. variations would be from 0.7 to 0.9 from start to end of the cycle.

Other loads operating at low pf are Arc welders and resistance welders. The pf is in the range of 0.35 Pf is corrected by connecting capacitors, across primary winding of transformers. The capacitors and transformers are switched as one unit. Due to intermittent nature of welding , correction to 0.9 or o.95 is not required. PF

control of 0.62 would give satisfactory operation . Recommended capacitors for various ratings are given in Table Appendix V.

5.4 LOSSES IN CAPACITORS

Table in Appendix VI indicates losses in different types of capacitors. Fuses, contactors, and switches are normally derated by 33% for capacitor duty.

6.0 ELECTRICAL DISTRIBUTION SYSTEM

The economic problems of distribution systems involve so many variables and differ so widely in objectives from one system to another that it is very difficult to set any rules that can be applied to all of them. The most economical is not always the one which is lowest in first cost. More important than first cost can be any of the various operating costs - total annual carrying charges, cost of losses or reliability of supply.

6.1 CABLE/LINE LOSSES, BUS BAR LOSSES

Cable /line losses which are the sum of $I^2R$of resistance losses can be found when the currents at peak load are known. Approximate/assumptions for simplifying calculation can be made depending on the distribution network. After calculating the peak copper loses, it will still be necessary to know to calculate the equivalent hours to calculate the actual copper loss over a length of time. The term equivalent hours is defined as the number of hours of peak load necessary to produce the same copper loss that is actually produced by the load over the selected period of time. The equivalent hours is a function of load factor. Graph in Appendix IX indicates the relationship between the % equivalent hours (or the loss load factor) to the % load factor. In this graph curve A shows the maximum percent equivalent hours possible for the range of values of load factor. Curve B shows the minimum possible values and Curve C shows the values which have been computed form typical load curves. Measures for minimising the energy losses in the distribution system have been discussed in the following paragraphs. Table in Appendix VII indicates the I^2R losses for different sizes of cables.

6.2 SELECTION OF SIZES OF CABLES/BUS BARS

Resistance is inversely proportional to the area of cross section of the conductor and hence higher the size of the cable lesser would be the energy losses. It is advisable to select the optimum size of the cables/busbars so that the I^2R losses are kept at minimum . If the size of the cable is found to be in- adequate (which also depends on the length of distribution) it is advisable to either replace the same with the higher size cables or provide additional circuits depending on the field conditions.

6.3 RATIONALISATION OF TAP POSITIONS OF TRANSFORMERS

It is necessary to maintain the specified voltage levels to evolve efficient operation of all electrical equipments. This would also minimise the energy losses in cables and busbars. Higher voltage results in lower line current and lesser losses.

It is advisable to examine the tap positions and also the incoming voltage levels periodically. The tap positions should be changed periodically to maintain optimum voltage levels. Whereas the OLTC's can be operated frequently, the off load tap changing gears should be operated less frequently (Occasionally) depending on the seasonal load variations and resulting variations in the incoming voltages.

6.4 LOCATION OF TRANSFORMERS AT LOAD CENTRES

As far as possible the transformers should be located at load centres or near the point where heavy loads are located. Circuitous feeding to the loads from the source should also be avoided. This would minimise the energy losses to a considerable extent. In some cases it may be feasible to rearrange the feeding of loads and circuitry in such a way as to bring the transformer to the load centre. Also the sharing of loads by cables/circuitry in an optimum way would also reduce energy losses to a considerable extent.

6.5 CASE STUDIES

Case Study - 1

Type of Industry : Mixed loads (Continuous process Foundry and Forge)

PROPOSAL

It was proposed to transfer the loads to an extent of about 240 KWs from Transformer No.1 to Transformer No.2.

Reduction in length of LT feeding : 240 Mtrs

Type of loads transferred : Compressor Motors

Estimated savings in energy losses : 46,000 kWh/year

Cost of investment : Marginal (as existing circuitry was rearranged)

Case Study - 2

Type of industry: Continuous Process and Engineering Fabrication (Mixed loads) Tap position of transformer : No.3 (as existing)

Lowest voltage recorded : 380 Volts

Highest voltage recorded : 405 Volts

PROPOSAL

It was proposed to shift the tap position of the transformer from 3 to 4.

Estimated savings in energy losses : 18,000 kWh/year

Cost of Investment : Nil

7.0 PLANNED PROGRAM FOR ENERGY CONSERVATION - CHECKLIST

A planned approach is very much essential for the implementation of the energy conservation measures. A check list indicating various measures (including House keeping routines) has been given in Appendix X.

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APPENDIX - I

DEFINITIONS : SYSTEM PARAMETERS

CALCULATIONS AND FORMULAE

1. LOAD FACTOR : $\dfrac{\text{Average Load over a designated Period}}{\text{Peak Load in that Period}}$

2. PLANT FACTOR : $\dfrac{\text{Average load on the plant}}{\text{Rated capacity of the plant}}$

3. CAPACITY FACTOR : $\dfrac{\text{Average Load on the machine}}{\text{Rated capacity of the machine}}$

4. DIVERSITY FACTOR :

a) Substation level :

$$= \frac{\text{Sum of the peaks of feeders}}{\text{Peak load on the transformer}}$$

b) Transformer (level)

$$= \frac{\text{Connected load on the Transformer}}{\text{Peak load on the Transformer}}$$

c) Distribution System

$$= \frac{\text{Sum of Maximum Demands offered by individual loads}}{\text{Simultaneous Maximum Demand of the system}}$$

5. Demand Factor

$$= \frac{\text{Maximum Demand of a system or part of a system}}{\text{Connected load of the system or part of the system}}$$

6. Loss load factor α $(LF)^2$

$$L.L.F. = \frac{\Sigma I_x^2}{I_{max}^2 \times 8760}$$

I_x = Load current I max = Peak load current

7. Transformer efficiency and Losses

a. Efficiency = Output(Power)/Input (Power)

b. All day efficiency = $\dfrac{\text{Energy output}}{\text{Energy output + Energy losses}}$

c. Total losses = Iron loss + Copper Loss (I^2 R Loss)

d. Iron Loss = k x t kWh

where K = Fixed loss in KW

t = time in hrs (of operation)

e. Copper loss = I x LLF x nf x t kWh

Where I = Full load copper loss in KW

LLF = Loss load factor

nf = efficiency at full load

t = time in hrs (of operation)

8. Operation of O.L.T.C.s

$$\text{Savings in energy losses} = 3\,R \int_{V_2}^{V_1} \int_{i_1}^{i_2} (I_t/n)^2 \, di \, dv$$

R = Resistance in ohms

I_t = Load current

n = no. of parallel paths

V_1 .....V_2 = Limits of voltage values under existing and proposed conditions

i_1 ......i_2= Limits of load current under existing and proposed conditions

9. Energy losses in cables and busbars

= I_x^2 x R x LLF x t kWh

Where I_x = Load current (Peak)

R = Total resistance

LLF = Loss load factor

t = Time in hrs (of operation)

10. Short time overload for oil immersed Distribution Transformers (Small capacitors) Ref: ASA: C-57-32-48

Duration :	A	B	C	D
	(Times rated current)			
30 min	2.0	1.89	1.77	1.57
60 min		1.60	1.54	1.40
4 hrs		1.37	1.33	1.24
2 hrs		1.19	1.17	1.12
8 hrs		1.08	1.08	1.06

LOAD CONDITIONS

A - Emergency - Following full load] with normal transformer
B - Recurrent - Following 50% load] life expectancy
C - Recurrent - Following 70% load]
D - Recurrent - Following 90% load]

11. LOAD MANAGEMENT AND DEMAND CONTROL

$$LSP = 1/\Delta T \sum_{i=1}^{n} t_2 \times t_{off}$$

Where LSP = Total possible load shedding potential

Δt = Demand interval in minutes

L_i = Load in kW under consideration for shedding

t_{off} = Allowable off time in minutes during the demand interval of the load

Note :

1. The LSP represents the maximum possible reduction in demand for the system through load shedding
2. Loads which are shed are restored after the Permissible plant

12. POWER FACTOR CORRECTION AND USAGE OF CAPACITORS

a) $I_T = \sqrt{(Iw)^2 + (Im)^2}$

Where I_T = Total current

Iw = Active component of Total current

Im = Reactive component (Magnetising component) of Total current

b) KVA = $\sqrt{(kw)^2 + (KVAR)^2}$

Where KVA = Apparent Power

KW = Real (or active) component of power KVAR = Reactive component of power

c) C KVAR = KW X (tan Q1 - tan Q2)

Where CKVAR = Capacitor rating in KVAR required to improve the power factor from existing value to a desired value

KW = Load in KW

Q1 = Cos (existing power factor)

Q2 = Cos (desired power factor)

COMPUTER SOFTWARE

13. CALM : Computer Aided load management
14. CATM ; Computer aided transformer load management
15. CASD : Computer aided system design

APPENDIX II

TABLE OF LOAD FACTORS

Sl No	Industry	Load Factor
1.	Plastic	.48
2.	Aluminium products	.31
3.	Chemical	.42 to .56
4.	Commercial Building	.41 to .45
5.	Mini Steel Plant	.62 to .64
6.	Vegetable Oil and Ghee	.70 to .83
7.	Foundry	.25
8.	Textile Mill	.81 to .90
9.	Chemical	.77
10.	Engineering (Bearing)	.44 to .50
11.	Dairy	.75
12.	Chemical	.65 to .71
13.	Engineering (Fabrication)	.33 to .37
14.	Chemical	.33 to .50
15.	Engineering (pump)	.26 to .49
16.	Engineering (Gears)	.30 to .40
17.	Textile Mill	.77 to .85
18.	Cement	.25 to .55
19.	Textile Mill	.37 to .64
20.	Vegetable oil	.56
21.	Spinning Mill	.72 to .80
22.	Mining	.56 to .71
23.	Textile Mill	.70
24.	Chemical	.70
25.	Paper	.65 to .75
26.	Abrasives	.55 to .65
27.	Chemical	.55 to .64
28.	Paper	.76
29.	Chemical	.47 to .59
30.	Chemical	.28 to .48
31.	Paper	.65 to .70
32.	Chemical	Near Unity
33.	Mineral	.22 to .47
34.	Chemical	.61
35.	Mini Steel	.42
36.	Vegetable oil	.50 to .63

APPENDIX - III

TABLE FOR SELECTION OF CAPACITORS

P.F of Load before applying Capacitors	Size of Capacitors KVAR/KW for changing P.F. to					
	0.80	0.85	0.90	0.95	0.97	1.0
0.40	1.537	1.668	1.805	1.959	2.037	2.288
0.45	1.230	1.360	1.501	1.659	1.737	1.988
0.50	0.982	1.112	1.248	1.403	1.481	1.732
0.55	0.769	0.898	1.035	1.190	1.268	1.519
0.60	0.584	0.714	0.849	1.005	1.083	1.334
0.65	0.419	0.549	0.685	0.840	0.918	1.169
0.70	0.270	0.400	0.536	0.691	0.769	1.020
0.75	0.132	0.262	0.398	0.553	0.631	0.882
0.80	—	0.130	0.266	0.421	0.499	0.750
0.85	—	—	0.136	0.291	0.369	0.620
0.90	—	—	—	0.155	0.234	0.481

APPENDIX IV

TABLE FOR SELECTION OF CAPACITORS FOR INDUCTION MOTORS (in K V A R)

Motor H.P.	Motor Speed (r.p.m.)			
	3000	1500	1000	750
5	2	2	2.5	3.5
10	3	4	4.5	5.5
15	4	5	6	7.5
25	6	7	9	10.5
50	11	12.5	16	18
100	21	23	26	28
150	31	33	36	38
200	40	42	45	47
250	48	50	53	55

APPENDIX - V

TABLE FOR SELECTION OF CAPACITORS FOR INDUCTION MOTORS (in K V A R)

Welding	Transformer Rating	Capacitor KVAR
9	(Single Phase)	4
12	(Single Phase)	6
18	(Single Phase)	8
24	(Single Phase)	12
30	(Single Phase)	18
57	(Three Phase)	16.5
95	(Three Phase)	30
128	(Three Phase)	45
160	(Three Phase)	60

APPENDIX VI
LOSSES IN CAPACITORS

Type	Loss W/KVAR
Paper Oil Impregnated	2.0 to 2.5
Paper PCB Impregnated	3.0 to 3.5
Plastic Film/ Paper, PCB	0.5 to 1.0
Plastic Film/ Paper, Oil	0.5 to 1.0
Metallised Film	Less than 0.5

APPENDIX - VII

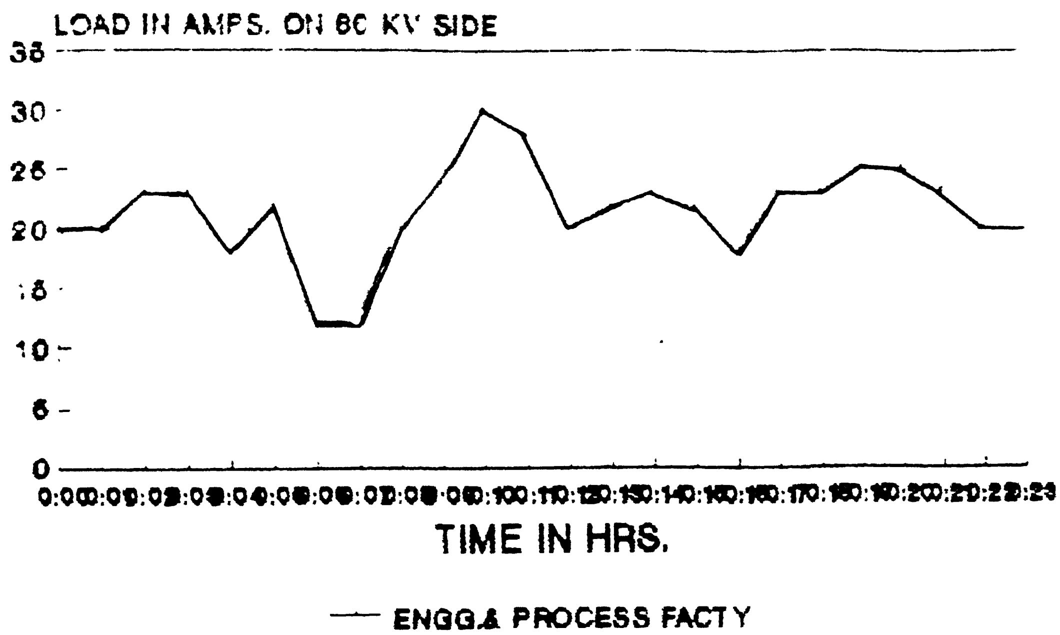
TABLE SHOWING LINE LOSSES FOR CABLES

I2 Losses For 10 Meters of Lengths For Various Sizes of Cables (Aluminium) Per Phase Losses, Watts/Cable Size, mm2

Size Amps	25	35	50	70	95	120	150	185	240	300
15	2.7	1.95	1.4	0.99	–	–	–	–	–	–
30	10.8	7.8	5.8	4.0	–	–	–	–	–	–
45	24.8	17.6	13.0	9.0	6.5	–	–	–	–	–
60	43.2	31.2	23.1	15.9	11.5	9.1	7.4	5.9	–	–
75	–	48.8	36.1	24.9	18.0	14.2	11.6	9.2	7.0	5.6
90	–	–	51.9	35.9	25.9	20.5	16.7	13.3	10.1	8.1
105	–	–	70.7	48.8	35.3	27.9	22.7	18.1	13.8	11.0
120	–	–	–	63.8	46.1	36.4	29.7	23.6	18.0	14.4
135	–	–	–	80.7	58.3	46.1	37.5	29.9	22.8	18.2
150	–	–	–	–	70.0	56.9	46.4	36.9	28.1	22.5
165	–	–	–	–	87.1	68.9	56.1	44.6	34.0	27.2
180	–	–	–	–	–	82.0	66.7	53.1	40.5	32.4
195	–	–	–	–	–	–	78.3	62.4	47.5	38.0
210	–	–	–	–	–	–	90.8	72.3	55.1	44.1
225	–	–	–	–	–	–	–	83.0	63.3	50.0
240	–	–	–	–	–	–	–	94.5	72.0	57.6
255	–	–	–	–	–	–	–	–	81.3	65.0
270	–	–	–	–	–	–	–	–	91.1	72.9
285	–	–	–	–	–	–	–	–	101.1	81.2
300	–	–	–	–	–	–	–	–	112.5	90.0
315	–	–	–	–	–	–	–	–	–	99.2
330	–	–	–	–	–	–	–	–	–	108.9
345	–	–	–	–	–	–	–	–	–	119.0

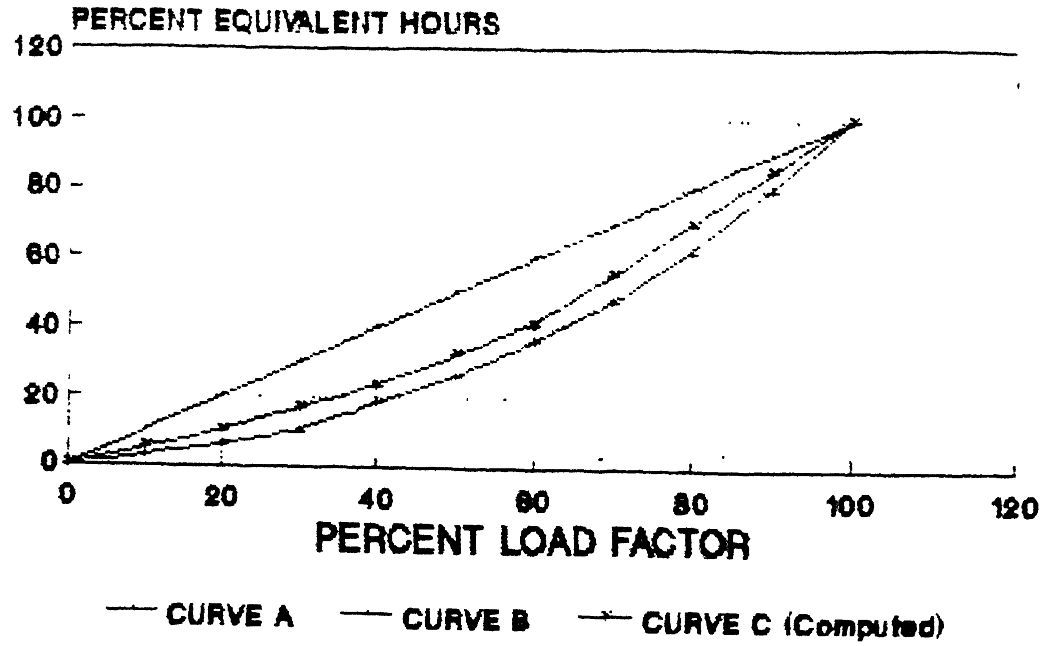
APPENDIX VIII

DAILY LOAD CURVE 14 MAY 91



TYPICAL WORKING DAY

APPENDIX IX
% EQUVT. HOURS Vs % LOAD FACTOR



APPENDIX X

CHECK LIST - ELECTRICITY UTILISATION

* Do you try to motivate the whole work force, from Senior management downwards, on the cost of electric power and the need to switch off any item as soon as its essential function has been performed?
* Are electric motors matched to actual load? Beware of adding unnecessary margins and try to monitor all motors occasionally with portable ammeters to see what is the true maximum load
* Have you considered a policy of buying high efficiency motors for any application where the motors run for more than say, five hours per day
* Do you have fairly large fans or pumps that run most of the time, and if so is delivery controlled by throttle dampers or valves? If so, consider saving is possible by new speed control systems
* When considering power to drive machinery , have you ever had a lubrication survey by one of the oil companies? Often the use of wrong oils or greases can cause an unnecessarily high power load These surveys are usually free and could show up to 5% power savings when nearly all the load is on machinery operations etc.,
* Do you try to use high speed motors on all new applications or when re-motoring existing plant? They are more efficient than slower running motors
* Are machines left run idle for long periods? If so try to find out why work people do this ; are there start-up difficulties that need to be overcome?
* Have distribution cables become overload due to addition of extra machinery and drives? Extra losses due to heating-up of cables are fairly small, but remember hazards of fire risk or failures which could stop production
* Are unauthorised appliances being used, e.g., Electric heaters in offices because of inadequate or fouled-up radiators or convectors. These can increase maximum demand charges
* Due you have off-peak electrical storage heaters? If so, have optimum charge controlled being fitted to control period of charge and delay start of charged until latest possible time? These do save considerable amount of electricity by reducing useless heating of rooms in early mornings with no occupancy etc.
* If storage heaters need replacing, consider fan assisted and thermostatically controlled units. These maintain better and more uniform room conditions and save energy during milder weather.
* Where tools, drives of heaters involve transformers, do this switch-off arrangement leave the transformers energised and wasting small but usually significant amount of energy?
* Can some electrical loads (usually heating ones) be transferred to another fuel if this is cheaper?
* If load is not apparently related to production very closely, are too many machines and motors running idle for long periods?
* Are motors correctly sized or too large actual duty?
* Investigate production methods to see if alterations can reduce load, particularly at peak M.D. periods. For eg., does a dryer need to be running all day or could better work programming and machine loading allow drying to be done in half the shift? Are any fans or pumps running with almost close dampers or throttle valves?
* Could monitor speeds be reduced or a smaller fan or pump be used, or one of the new speed variation controllers used instead of the throttling system?

2. INDUSTRIAL ILLUMINATION

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APPENDICES

INDUSTRIAL ILLUMINATION

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1.0 INTRODUCTION

Great deal of work has been done all over the world during the last 5 decades by various professional bodies to determine the fundamental visual requirements. This is partly reflected in the B.I.S. code for interior lighting and it provides the basis for lighting practices in the country.

The standard service illuminances recommended in the code are themselves not the sole criteria of good lighting for other factors such as visual comfort, the colour of the light and the atmosphere of an installation must also be taken into account. Following basic requirements should be ensured by a good lighting system - viz. Acceptable visibility, - Sufficient visual satisfaction, - Security

2.0 LIGHTING AND ENERGY

Lighting loads account for about 5 - 15 percent of electricity consumption in an industrial plant. The actual quantity depending on the type of industry. Lighting system offers wide scope for conservation of energy. The basic approach of energy efficient lighting is based on the following :-

1 Designing of illuminance should be task oriented ie., illuminance required for the particular task only should be provided . There is no need to provide uniform illuminance everywhere. Additional local sources should be provided for difficult visual tasks.

2. Selection of proper light source

3. Control and maintenance

It should noted that the efficiency of the lighting system is a critical factor than the initial cost of the system, since any extra cost involved in purchase of more efficient system is recovered within a short period through savings in energy consumption.

2.1 FACTORS INFLUENCING ENERGY USE

There are several factors influencing energy use in an installation for a given lighting standard.

i) Lamp efficacy (light output per watt of electrical power consumed of the lamp type used)

ii) Luminaire (lighting fitting) performance;

iii) Lighting scheme design ;

iv) The decor and furnishing;

v) Maintenance standards

vi) Proper use of switching and contrcls

The factors i) to v) relate to fundamental efficiency of the installation and (vi) with management and use of the installation.

It is necessary to assess the true cost of a lighting system when evaluating the performance.

This is not a matter of simply comparing the cost of lamps and luminaires. It is easy to overlook some of the other costs involved such as reduced no. of luminaires. Use of controls, the reflectance of surfaces, the amount of glazing and the pattern use of the premises. It is also necessary to assess the advantages of alternate capital costs and payback periods.

2.2 LAMP EFFICACY

There are broadly two types

- Tungsten filament type and
- Discharge type (includes fluorescent tubes)

Luminous efficacy is defined in lumens per watt and account should be taken of the control gear loss of fluorescent and discharge lamp circuits. While designing a new installation, the type selected should have as high an efficacy as possible and with characteristics that suit the requirements of the installation - colours, life,etc.

For existing installations, a change to a more efficient lamp type will reduce energy consumption. Fluorescent lamps and discharge lamps need some form of starting device (starters) and means of controlling the lamp current once started (ballast). A capacitor is also normally connected to provide power factor correction and reduce the current drawn from the mains for a given wattage.

2.3 LUMINAIRE

The main function of the luminaires are to support and protect the lamps, provide the electrical connections to supply and to control and direct the light emitted by the lamps.

The LOR (Light Output Ratio) of a luminaire is the ratio of the light output of the luminaire to that of the lamps. It is not a measure of efficiency in practical application.

A bare fluorescent lamp in a batten type luminaire has a high LOR, but more light will reach the working place beneath the lamp if suitable reflector is fitted to redirect the light even though the LOR is reduced.

The most efficient luminaire is one which maximises the lighting result by the most suitable combination of appropriate light distribution and LOR.

The efficacy of a lamp/luminaire combination when used to provide general lighting in the interiors can be expressed by the utilisation factor.

$$\frac{\text{Luminous flux at the working place}}{\text{Luminous flux emitted by the lamp}}$$

Other design criteria for the installation, particularly glare must be taken into account.

3.0 ENERGY AUDIT APPROACH

As already indicated lighting system offers good scope for minimising energy consumption. This can be achieved by implementing conservation measures and good house keeping routines.

A number of new products and energy efficient fittings have been become available and advantage of these products can be taken for saving of energy.

By experience it is observed that illuminance in most industries in our country is much less than required for visual comfort and productivity. Recommended values of illuminance as per BIS 3646 has been tabulated in Appendix-I. A good lighting system should ensure adequate illuminance levels to improve the quality of production and minimise rejections/recycling. This would result in conservation of energy in process and savings in labour costs and new material also.

To assess the quality of lighting and link it with energy consumption, it is necessary to make certain measurements and define several quantities/properties connected with illumination. The general terminologies used along with definitions and formulae used for calculation has been placed in Appendix II.

Measuring instruments and Measurements to be made are discussed in the following paragraphs.

3.1 MEASURING EQUIPMENTS AND MEASUREMENTS

For evaluating an actual lighting installation in the field it is necessary to measure or survey the quality and quantum of lighting in a particular environment. The measurement of illuminance is necessary

- to check the calculated value of the new installation
- to determine compliance with the specification or recommended practice as per BIS.

Field measurements relate only to conditions that exist during the survey, recognising this the following detailed description of the survey area and factors which might effect results are noted they are

- Lamp type and age
- Luminaire and Ballast type
- Voltage
- Interior surface reflectance
- State of maintenance
- Last cleaning date

Measurements of illuminance should be done using a standard lux meter. The reading of the lux meter should be independent of the colour of the light source. Also it should be corrected to take account of the effects of light falling on it an oblique angle (cosine correction).

Measurements are normally carried out after dark in order to exclude all the day light from the interior. However, during the day time also measurements may be made for purpose of comparison and checking with standard recommendations.

Before starting the measurements, all the lamps should be switched on and then light output should be allowed to stabilise for about fifteen minutes.

The area to be measured has to be divided into squares with sides of 2 mtrs (approximately) and the illuminance has to be measured at the centre of each square, at the height of working plane. A portable stand may be used

to mount the photo cell at correct height and at a horizontal position. The average illuminance of the whole area can be obtained by averaging all these measurements.

The number of measuring points can be selected depending on the room index noted below:-

Room Index	No. of Points
Below 1	4
1 & below 2	9
2 & below 3	16
3 and above	25

The illumination at the task area should be measured with the worker in his normal working position.

The cylindrical illuminance can be measured by using a special adopter along with the same photo cell.

3.2 QUALITY OF LIGHTING INSTALLATION

The following parameters determine the quality and quantity of illuminance :

- Average illuminance
- Uniformity of illuminance
- Cylindrical illuminance
- Luminance ratio in field of view
- Reflectance of surfaces
- Glare rating
- Shielding angle
- Corelated colour temperature
- Colour rendering index

Average illuminance refers to the average value of the horizontal illuminance in the working plane. In the case of general lighting the ratio of minimum illuminance to average illuminance will not be less than 0.8.

In industrial applications cylindrical illuminance is equally important as that of horizontal illuminance. The ratio of the cylindrical illuminance to horizontal illuminance (i.e., shadow factor) should between 0.2 and 0.5.

The values of reflectances should be within the following range :-

	Main value	Max. Value
Ceiling	60%	80%
Floor	10%	30%
Wall	30%	80%

Advance software for evaluation of illuminance of existing systems and for designing new lighting system have been developed which could be made use of for energy audit of lighting system.

4.0 EVALUATION OF LIGHTING SOURCES

Advantages and disadvantages of different types of lighting sources should be analysed in an objective way so as to select the required type which results in energy conservation also. Appendix - III presents a qualitative comparison of different types of lighting sources.

4.1 Natural day light is available in our country almost throughout the year. Maximum use must be made use of this source of light. A large number of industries have taken advantage of this in last few years. By using glass or transparent sheets at suitable places in roofs and lighting consumption can be considerably reduced.

4.2 Characteristics of different types of lamps have been tabulated in Appendix IV. HPSV luminaires offer maximum scope for energy conservation. The pie charts given in Appendix V illustrate the efficacy of HPSV lamps. For industrial high bay lighting (height more than 6/7 metres) high pressure sodium vapour lamp would be a preferred lighting source. For light industries (lowbay height 6/7 metres) fluorescent lamps are preferred For street lighting, security lighting, warehouse low pressure sodium vapour lamps may be used. Other design aspects must be considered while selecting the efficient light source.

4.3 Proper luminaire should be selected so that light is provided where it is required. Many fluorescent fittings without proper luminaires give half the light to the ceiling rather than illuminating the floor.

4.4 The height of light source is an important factor to be considered. It is known that the illuminance at a given level varies as inverse square of the distance. Many industries have lowered height of tube lights and saved significant amount of energy.

4.5 Walls and other reflecting surfaces should be painted with light colours. Heavy and dark colours absorb lot of light leading to less reflection and less light where required. This also leads to higher power consumption as more lights are to be provided to a given level.

5.0 ENERGY CONSERVATION MEASURES

Apart from selection of proper lighting source, luminaire and illuminance design etc.,discussed earlier , following additional measures are discussed for adoption depending on the requirements in individual cases.

5.1 TASK LIGHTING

Task lighting is one of the most effective way of providing illumination at low cost. In medium/large industries providing localised lighting for a working area equipment wise /machine- wise would result in conservation of

energy to a great extent. In existing systems it is observed that 60 W GLS lamps (sometimes even 100 W) are being used where 40 W lamps would suffice. Proper selection of wattage of lamps would result in savings in energy consumption. Fluorescent tube lights may also be considered for providing task lighting designs (especially in Textile industries) for effective conservation of energy.

With provision of task lighting, the general lighting demand would get reduced as the illumination level required would be less for general activity.

5.2 ELECTRONIC BALLAST

The efficiency of fluorescent tube increases when working at high frequency (20 to 30 KHZ) than at normal 50 HZ. In last few years, advances in electronics have made it possible to develop simple electronic convertors for converting 50 Hz supply to 35 to 40 KHZ supply. This is called as electronic ballast (or solid state choke). Conventional Ballast, starters and capacitor are not required with this ballast. Power consumption of this ballast is 1 watt. In conventional types of ballast (ie., magnetic) the power consumption would be around 15 watts. Hence efficiency of lighting improves by 10%. Actual test results show a saving of about 20% to 25% in energy after using these ballasts. They provide instant start. Appendix V illustrates the salient features of electronic ballasts in comparison to conventional chokes.

5.3 VOLTAGE CONTROLLERS

A slight reduction in operating voltage, in case of fluorescent tubes would result in savings in consumption to a considerable extent without affecting lighting levels appreciably. However, the illuminance would get reduced marginally. A separate voltage regulator which supplies about 380/390 volts to lighting circuit will lead to energy savings. During off peak hours (especially during nights), the increase in voltage results in higher consumption in lighting circuits.

In large /medium scale industries and in other industries where the lighting consumption is considerably high, it would be economically viable (and technically feasible) to have separate 11 KV/240V - 3 phase transformers exclusively for lighting circuits. By operating the tap positions (off load taps) of these transformers it is possible to maintain the required optimum voltage to minimise the energy consumption in selected lighting circuits. Apart from energy conservation, such an arrangement would also provide better flexibility in operation of transformers, and facilitate independent supply for emergency, and essential lighting circuits like security, watch & ward, stores, etc.,

5.4 36 W SLIM TUBES

36 Watts slim tubes are available in the market and these tubes can be used wherever conventional type 40W tubes are used. This would reduce the consumption of energy to a considerable extent without any loss of illuminance.

5.5 NEW TECHNOLOGIES

As already discussed good deal of development has taken place in the design of new luminaires with good reflecting surfaces. Many manufacturers have launched new type of energy efficient fittings with better illuminance levels which need to be tried.

One of the latest significant development is miniature fluorescent tubes. These tubes have been developed in the rating of 5,9,11 watts to replace conventional 25, 40, 60 and 100 watts incandescent lamps. Energy savings is expected to be around 80% . Life of the lamp is about 6 to 7 times more than the GLS lamp. Initial cost would

be high, but with mass manufacturing it is expected to cost less. These would be ideally suitable for providing task lighting discussed earlier.

6.0 SWITCHING AND CONTROLS

The purpose of controls is to see that lighting is provided in the right amount, in the right place for the required time. Even with efficient lamps and luminaries etc., energy used for lighting can be wasted in different ways. Close studies have revealed that in general, people turn on the light only when they need it, but fail to turn off when it is not required . While exhortation can be helpful in short term, the ideal solution would be to provide some form of control for switching off.

A source of unnecessary use results from the common practice of controlling large areas of lighting with small number of switches, such that individual requirements are met by turning on all luminaires.

Use of time switches provide a simple cost effective solution. In many factories lights are switched off in recess hours by time switches.

It is reported that in one machine tool industry, trollies, fitted with lights were provided, for use in 2nd and 3rd shifts. During these shifts, only few machines would be in operation and the general lighting is switched off and only few passage and trolley fitted lights were used.

Controls are very effective in reducing lighting costs but involve capital costs. However, a cost benefit analysis has to be worked out before designing the necessary switching controls.

7.0 MAINTENANCE

Maintenance of luminaires and reflecting surfaces is very important. Generally a 'fit' and ' forget' tendency prevails. One consequence of this is that the illuminance would get reduced. There are instances where (especially task lighting) lamps of higher wattage were used instead of cleaning the reflecting surface resulting in the increased consumption for the same level of lighting. Studies and measurements have revealed that there would be a marked increase in illuminance after the reflecting surfaces were cleaned.

Efficiency of lamps reduce with time, collection of dust and dirt further reduces the light output with time. Regular cleaning and replacement of lamps is helpful in maintaining lighting levels and efficiency.

Implementation of house keeping measures should be ensured for proper maintenance and achieve energy conservation. A check list of housekeeping measures has been placed in Appendix-VI. Periodical painting white washing will help in improving the efficiency of lighting system without increasing the luminaires.

8.0 CASE STUDIES

CASE STUDY-1 : Type of Industry : Textile

Type fittings used : 2 x 40 W Fluorescent tubes light fittings

Illuminance measured : 130 to 260 Lux

Proposal : Task lighting for selected sections where fluorescent fittings are used.

Area covered by task lighting: '2 Sq.Meter

Shadow factor : 0.5

Vertical Illuminance : 465 Lux

Horizontal illuminance : 930 Lux

Savings in energy consumption = 2.07 lakh kWh/Year

Estimated cost : Rs. 6.00 Lakhs

(Net cost) taking into consideration the cost of present fittings)

Simple payback period : About 2 1/2 Years

CASE STUDY - 2

Type of Industry : Textile

Type of fittings used : Fluorescent tube light

Fittings 2 x 40 W with conventional chokes

PROPOSAL

Replacement of conventional ballasts by Electronic Ballasts

Estimated savings in energy consumption : 89,900 kWh/Year

Cost of implementation : Rs. 2.80 Lakhs

Simple pay back period : 2 1/2 Years

CASE STUDY - 3

Type of Industry : Continuous process/Engineering (Mixed loads)

Type of fittings used : 2 x 40 W Fluorescent tube light fittings

Voltage control : Independent transformer 11 KV/240V 3 ph for lighting loads provided.

Present tap position : No.3

Existing voltage conditions :

230 Volts during peak period

250 Volts during off peak loads

PROPOSAL

To change the tap position to No.1 and reduce the voltage by 5%

Estimated savings in energy : 13,500 kWh/Year

Cost of Investment : NIL

APPENDIX - I

RECOMMENDED VALUES OF ILLUMINANCE AS PER BIS 3646

Process	Illumination Lux	Limiting glare index
* Factory areas :		
Entrances, corridors, stairs	100	...
Canteens	150	...
Cloak rooms	100	...
Stock-yards, main entrances & exit road, car parks	20	...
Stock parts production	450	25
* Drilling, rivetting, screw fastening, welding, coiling, final assembly and inspection	300	25
* Maintenance and repairs	300	25
* Assembly Shops :		
Rough work	150	28
Medium work	300	25
Fine Work	700	22
Very Fine work	1500	19
* Boiler Houses :		
Coal and ash handling	100	...
Boiler fronts and operating areas	100	...
Other areas	20 to 50	...
Cat walks	20	...
Platforms	50	...
* Chemical Works :		
Hand furnaces,boiling tanks stationery driers, evaporators, filtration plants, extractors and electrolytic cells	150	28
Controls, gauges, valves, etc.	100	...

Process index	Illumination Lux	Limiting
* Foundries		
Charging floors, tumbling cleaning, pouring, shaking out and core making	150	28
Fine moulding and core making, inspection	300	25
* Iron and Steel Works		
Marshalling and outdoor stock-yards	10 to 20	...
Stairs, gangways,basements quarries and loading docks	100	...
Slab yards,melting shops, ingot stripping, soaking pits, and pump houses	100	28
Mould preparation, rolling and wire mills, mill motor rooms and power houses	150	28
Plate inspection	300	...
Tin plate inspection Special lighting Process Illumination Limiting in Lux Glare index		
* General Laboratories, balance rooms.	300	19
* Electrical and instrument laboratories	450	19
* Machine and Fitting shops		
Rough bench and machine work	150	28
Medium bench and machine work	300	25
Fine bench and fine work	760	22
* Motor Vehicle Plant		
Car assembly, chassis assembly	300	25
Final inspection	450	25
Trim shops and body assembly	300	25
Spray booths	450	...

Process index	Illumination Lux	Limiting
* Paint shops		
Dipping, firing, rough spraying	150	25
Rubbing,ordinary painting spraying	300	15
Retouching and matching	700	19
* Pharmaceuticals and Fine chemicals works		
Raw material storage	200	28
Control laboratories and testing	300	19
Manufacturing	300	25
Fine chemical finishing	300	25
* Textile Mills		
Bale making, blowing, carding, spinning heckling, cabbing	150	25
Wrapping, slashing, dressing and dyeing	200	25
Weaving	700	19
Cloth inspection	700	19

APPENDIX - II

DEFINITION AND GENERAL FORMULAE

1. ILLUMINANCE

It is the diversity of the luminous flux incident on a surface, it is the quotient of the luminous flux by the area of the surface where the latter is uniformly illuminated. The term illumination is used to designate the act of illuminating or the state of being illuminated.

Lux is the International system, (SI) unit of illuminance where the meter is taken as the unit of length.

2. LUMINANCE (PHOTOMETRIC BRIGHTNESS)

It is the quotient of the luminous flux leaving or arriving at an element of a surface and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone, and the area of the orthogonal projection of the element of the surface on a plane perpendicular to the given direction; or it is the luminous intensity of any surface in a given direction per unit of projected area of the surface as viewed from that direction.

Candelas per square meter is the SI unit of luminance.

3. COLOUR RENDERING INDEX

Colour rendering index of a light source is the measure of the degree of colour shift which objects undergo when illuminated by the light source, as compared with the colour of those same objects when illuminated by a reference source comparable. Index values for common light sources vary from 20 to 99. The higher the number, the better is the colour rendering index.

4. LUMINOUS FLUX

It is the time rate of flow of light :

$Q = dq/dt$

Unit is lumens

5. LUMINAIRES

They are complete lighting units consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply. They are classified by the CIE (International Commission on Illumination) according to the percentage of light output above and below the horizontal as follows :-

Classification	Upward	Downward
Direct	0 - 10%	90 - 100%
Semidirect	10 - 40%	60 - 90%
General diffuse	40 - 60%	40 - 60%
Semi indirect	60 - 90%	10% - 40%
Indirect	90 - 100%	0 - 10%

This classification system applies to all types of luminaires for general lighting in industrial, commercial and residential applications. Luminaires are designed to redirect light and to increase the effective light source area, thus decreasing brightness while absorbing no more of the light flux than necessary.

6. LIGHTING SYSTEMS

Lighting systems are installations of one or more luminaires and are often classified in accordance with layout or location with respect to the visual task or object lighted - eg. general lighting/ localised general lighting, localised/task lighting.

7. AVERAGE ILLUMINANCE

It refers to the average value of the horizontal illuminance in the working plane which is a horizontal plane and at a height of 0.85 mtr from the floor.

8. UNIFORMITY OF ILLUMINANCE

The illuminance obtained with any lighting installation in practice will never be completely uniform over the entire surface. The minimum illuminance is the lowest illuminance at any relevant point of the reference.

In the case of general lighting, the ratio of minimum illuminance to average illuminance will not be less than 0.8 at the reference surface in order to provide equivalent task locations throughout the interior.

9. CYLINDRICAL ILLUMINANCE

It is a measure of the light falling on a flat vertical surface. It is defined as luminous flux incident on the curved surface of an infinitely small cylinder (at a height of 1.2 mtr i.e., eyelevel) divided by the area of the surface.

10. SHADOW FACTOR

The ratio of cylindrical illuminance to horizontal illuminance is defined as shadow factor. Ideal value of this factor should be in the range of - $0.2 < E_{cyl} / E_{hor} < 0.5$

11. LUMINANCE RATIO IN FIELD OF VIEW

Illuminance is a measure of light reaching on the working place. It is invisible to the eye. Only the reflected light (luminance) is visible as it is the messenger that carries to our eyes and creates a visual sensation.

12. GLARE RATING

Glare is a condition of vision, in which unsuitable distribution on range of luminances in the visual field will create discomfort and

13. ROOM INDEX

Room index K = a.b/ h (a+b)

Where K	=	room index
a.b	=	Sides of the room
h	=	height of luminaires above work plane

14. CALD :

Computer Aided lighting design. Complex situations and calculations involved in designing energy efficient lighting design are handled using a computer.

15. ADVANCED SOFTWARE

Software developed for design of energy efficient lighting system with the aid of computer

16. VISIBILITY DIAGRAM

A computerised graphical representation of horizontal vertical and cylindrical illuminance of different areas

17. ILLUMINANCE DIAGRAM

Diagram indicating the variation of average, minimum, and maximum illumination level in the horizontal plane. With the help of this computer graphic it is possible to get a clear picture regarding the evenness and quantitative aspect of lighting.

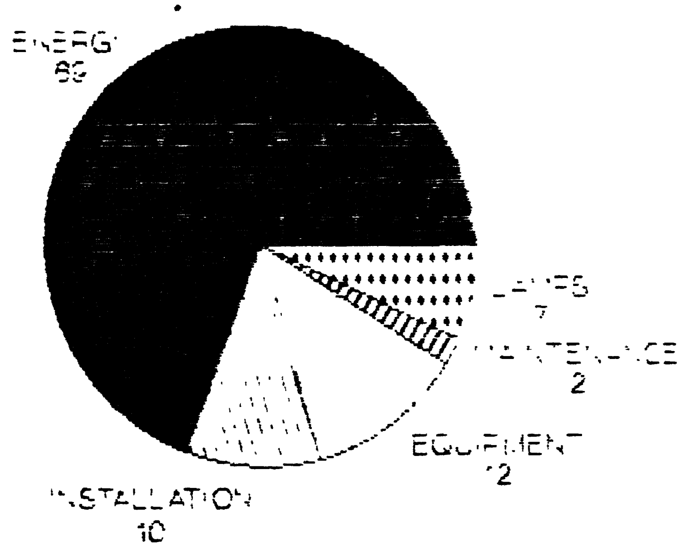
APPENDIX III

QUALITATIVE COMPARISON OF DIFFERENT TYPES OF LIGHT SOURCES

Lamp	Wattage	Luminous Efficacy (lm/W)		Colour Rendering Index	Average Life in Hours
		Lamp	Lamp + Ballast		
Tungsten Incandescent (GLS)	25 - 1000	8 - 13	–	100	1000
Tungsten Halogen	1000	22	–	100	2000
Fluorescent					
(i) Cool day	i) TL 20/40/65	49 - 62	32 - 50	77	5000
	ii) TL 18/36/58	54 - 58	34 - 54	65	5000
(ii) White	i) TL 20/40	58 - 69	38 - 54		
	ii)TL D 18/36	64 - 77	41 - 58		
Blended Lamp	160/250	18 - 21	–	50	5000
High pressure Mercury Vapour	80 - 1000	44 - 57	38 - 54	45	5000
High pressure Sodium Vapour	150/250/400	90 - 118	79 - 107	25	More than 12000
Low pressure Sodium Vapour	35	125	91	–	More than 12000
Compact fluorescent	9	67	46	85	7500
Metal Halide	250 - 2000	68 - 95	63 - 90	70	For 460 W more than 8000 For 1000/2000 W more than 6000

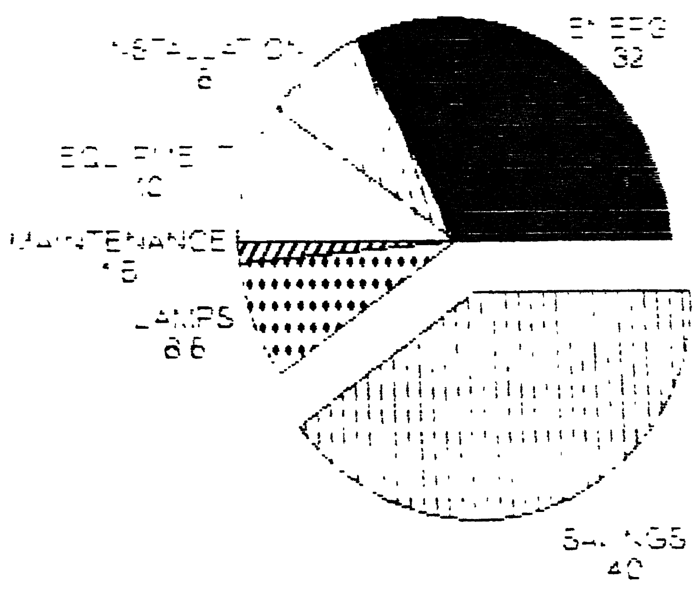
APPENDIX IV

ANNUAL LIGHTING COSTS
H.P.MERCURY VAPOUR LAMPS



FIGURES IN PERCENTAGES

H.P.SODIUM VAPOUR LAMPS



APPENDIX - V

SALIENT FEATURES OF ELECTRONIC BALLAST

Characteristics	Electronic Ballast energy saver	Good quality Conventional Choke
1. Power consumption in Ballast	1 Watt	15 Watts Typical
2. Power consumption of Total Fixture	37 Watts	55 Watts Typical
3. Operating voltage range	120 to 265V	190 to 250 V
4. Noise level	Nil	Nil
5. Lamps functioning		
a. Flickering	Nil	Present
b. Starting	Instantaneous	Delayed
c. Light output	2800 Lumens (Ave)	2500 Lumens (Ave)
d. Life of Lamp	7500 hrs	5000 hrs
e. Functioning at low temp.	Works even at -10°C	Cannot operate at low temperature
6. Starter on Fitting	Not required	Required
7. Temperature Rise	Negligible	Atleast 10°C to 15°C over ambient
8. Power factor	Nearly unity	0.55
9. Condenser Provision	Not required	Required for power factor improvement
10. Weight	Very light (120gms)	Heavy (Over 600 gms)
11. Lamp efficiency	68 Lumens/Watt	45 Lumens/Watt
12. Protection	Double protection Fuse and thermistor	No protection

APPENDIX - VI

CHECK LIST - ELECTRIC - LIGHTING

* Are internal lights left on unnecessarily? This can be a large opportunity for financial saving with modern control system, also are staff properly motivated to 'switch off'?
* Are the most efficient types of lamp/tube being used? Many recent advances towards more efficient lamps have been made do not automatically buy the same replacements The tungsten filament bulb now be ruled out for any relatively continuous use Fit slimline tubes as replacements in older switchstart fluorescent fittings
* Consider using high frequency control gear and ballasts to operate standard fluorescent tubes to obtain higher efficiencies of light output against electrical input This should particularly be considered when fittings need replacing or a new building is being equipped
* Consider replacing MBF/U mercury lamps by more efficient high pressure sodium lamps using conversion controls now available to convert present lampholders
* Are external car park and security lights left on unnecessarily? Use time-of-year clocks or photocell controls
* Are the light fittings themselves giving the best output? Dust and dirt fouling can seriously reduce the output, so clean regularly The fittings may give the wrong distribution of light for the particular room or type of work
* Are the illumination levels the most suitable? Too high a level wastes energy ; too low a level may increase mistakes , slow down work speeds or even cause accidents
* Are correct colours used on walls, ceilings, furnishings and machines, to give a reasonable reflection of light but avoid glare, to give reasonable constraint with material being processed?
* Are the lighting switches properly positioned? How far does someone have to walk to turn the lights over their workstation on or off? Too far and they will be left on even if daylight gives sufficient illumination
* Are the number of lights per switch excessive? If some people are absent can the lights over their work station be turned off? Often this cannot be done as the switch also controls the lights over other stations where staff need light
* Have you investigated possible installation of any of the automatic control systems? These can give very large savings in suitable cases? They can be activated by light sensors or personnel sensors
* Does the switching system (manual or automatic) allow selective switch-off lights nearest to windows when day light is adequate
* Have you considered small desk or drawing board lights to give a local higher illumination level rather than have a high level over the whole of a large room?
* When high lighting levels are genuinely required , have you chosen good fittings which emit a high proportion of lamp output, but do not cause excessive layer which can create eye strain or complaints?
* Do you have a regular cleaning programme for lamps, reflectors and glass panels in lighting systems to minimise loss of illumination? Frequency depends on quality of atmosphere.

* Have you borrowed (or purchased) a simple light meter to check for correct illumination levels at workstations so that, where necessary, lighting can be rearranged or locally reinforced Such a meter will also help decide on intervals between cleaning since it will indicate gradual loss of outputs due to dust etc ,

* Have you considered reducing lighting levels in little used areas, corridors, stores etc , by removing chokes or tubes?

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